# NAVAL POSTGRADUATE SCHOOL
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# THESIS

**ARMY INVENTORY POLICY,
THE NEED FOR STRATEGIC CHANGE:
AN EXAMINATION OF READINESS BASED SPARING
FOR RETAIL REPAIR PARTS SUPPLY SUPPORT**

by

Robert D. Brem

December, 1997

Primary Advisor: Kevin R. Gue
Associate Advisor: Michael W. Boudreau



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# ARMY INVENTORY POLICY, THE NEED FOR STRATEGIC CHANGE: AN EXAMINATION OF READINESS BASED SPARING FOR RETAIL REPAIR PARTS SUPPLY SUPPORT


Robert D. Brem
Captain, United States Army
B.S., Lafayette College, 1989


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**December, 1997**

Author: Robert D. Brem

Robert D. Brem

Approved by: KRGue

Kevin R. Gue, Primary Advisor

Michael Boudreau

Mike Boudreau, Associate Advisor

Reuben T. Harris

Reuben T. Harris, Chairman
Department of Systems Management

# ABSTRACT

Army Vision 2010 and Focused Logistics has recognized the need for a Revolution in Military Logistics to support the Revolution in Military Affairs in the information age. As well, readiness needs are increasingly having to be balanced with fiscal realities. Readiness Based Sparing inventory models can give commanders the tools necessary to make these critical resource allocation decisions.

We explore the potential value of implementing a Readiness Based Sparing policy for Army retail level, repair parts inventory management. We answer questions of effectiveness, implementation and potential barriers to implementation. In doing so, we offer a description and analysis of current policy, its effects and consequences. We present an introduction to Readiness Based Sparing methods, their evolution in military applications, successful implementations and lessons learned. We compare the performance of Authorized Stockage Lists determined using Readiness Based Sparing with those under current policy. We address issues of cost, supply performance, mobility, manpower, and transition to war, among others.

From this analysis we conclude that Readiness Based Sparing methodology is superior to current methods of stockage determination and recommend that the Army embrace it as the preferred retail inventory policy. We suggest means for implementation and areas for further research.

## TABLE OF CONTENTS

# I. INTRODUCTION

This research will explore the potential value to the Army of implementing a Readiness Based Sparing (RBS) model for management of its retail level inventories. Specifically, this research will look at 1) the differences in how ranges and depths of retail stocks are currently determined as compared with an RBS model and 2) the impact of those decisions on the suitability of the stockage in our current high-paced yet fiscally constrained environment.

## A. RESEARCH QUESTIONS

We answer the following primary questions:

1. **Can Army implementation of an RBS model at the retail level achieve readiness goals at less cost than the current policy?**
2. **If so, what is the process by which RBS might be implemented for Army retail level applications?**
3. **What are the potential technical and cultural barriers to implementation, and how can they be overcome?**

## B. SCOPE

We focus on applications of RBS at the retail level of the supply chain, with due consideration to its interaction with customer and wholesale levels as appropriate. Our methodology consists of four basic steps:

- First, we conduct a thorough literature review on relevant topics to support discussion of the need for better management of Army repair parts inventories; the current policies relating to retail inventory management; the

current procedures for determining range, depth and replenishment of stock; the theoretical basis of RBS; and the evolution of RBS in Military applications.

- Second, we compile the results of several recent Army studies of RBS in retail applications. We present the comparative performance of RBS ASLs with respect to those of current policy.

- Third, we analyze the results in terms of parameters such as Gross Effectiveness, Range and Depth, Inventory Value (dollars), and Inventory Size (weight and cube). We identify some advantages and limitations of the RBS model in Army retail applications to include potential barriers to implementation of such a policy and the means to overcome them.

- Finally, we make conclusions based on our research, with specific recommendations regarding further exploration of RBS in Army inventory applications.

## C. ORGANIZATION

There are five remaining chapters. In Chapter II, we establish the contextual environment in which this study was made. We describe where the Department of Defense (DoD) and the Army component are in terms of current readiness posture and the status of the inventories to support that level of readiness. We document where the DoD

and Army want to go in terms of the logistics necessary to support global operations in the next century. We describe the Army strategy to achieve its long range logistics objectives. Finally, we address potential pitfalls in achieving those objectives.

Chapters III and IV describe the two policies that were evaluated. In Chapter III, we describe and analyze current policies for the management of Army retail parts inventories and the effects that implemented practices of these policies have on inventory investment and readiness. Chapter IV introduces Readiness Based Sparing as an alternative policy for retail inventory management. A brief theoretical presentation is followed by several examples of successful implementation of RBS in both commercial and military environments. Chapter V presents a comparative performance analysis of RBS ASLs with respect to those of current policy. Chapter VI provides our conclusions and recommendations.

# II. BACKGROUND

## A. WHERE WE ARE

During the Gulf War, the Army demonstrated that it was indeed a modern, quality force. However, there were indications that some logistics changes needed to be made. Many units had been trained to receive pre-positioned equipment in a European Scenario of the Cold War Era. Analysis of numerous lessons learned from the deployments of 1990 indicated that some of these units had not paid particular attention to the readiness of their organic equipment. When the call came to deploy with their own equipment, they were not ready.

With the drawdown that followed the Gulf War, the Army realized that organic equipment readiness was a cornerstone of the Force Projection Strategy. Since then, much emphasis has been placed on sustaining readiness resource levels and readiness is purported to be the best ever as described by General John Shalikashvili, former Chairman of the Joint Chiefs of Staff:

> What an extraordinary success this drawdown has been. For the first time in history, we have been able to reduce as significantly as we have reduced without taking a nose-dive in readiness.... While we are considerably smaller today than we were when the Cold War ended, pound for pound we are as ready today as we have ever been.[Ref. 1:p. 25]

However, there is mounting evidence from many sources that readiness may not actually be what it appears. The Honorable Floyd D. Spence, Chairman of the House Committee on National Security reported in his 1994 review of military readiness that:

> ...wholesale categories of combat units [were] managing to preserve short-term readiness only through engaging in a desperate 'shell game' with dwindling resources.[Ref. 2:p. 1]

In his most recent review, Chairman Spence stated that the "indicators of a long-term systemic readiness problem are far more prevalent than they were in 1994." One senior military commander quoted in the report linked reduced training proficiency to increased expenditures for equipment maintenance. "Every dollar [paid] for maintenance is a dollar subtracted from training for operations."[Ref. 2:pp. 1,9]

But, the pace of operations (OPTEMPO) continues to age equipment prematurely, thereby steadily increasing the demand for decreasing resources. Further exacerbating the strain on resources is the need to modernize our military equipment, particularly in the Army. As with many corporations in the private sector, cost savings in logistics operations is the primary source of funds for this modernization effort. Secretary of Defense William S. Cohen, defined this target in his 1997 Annual Report to the President and Congress:

> ...every logistics dollar expended on outdated systems, inefficient organic capability and excess inventory is a dollar not available to build, modernize or maintain warfighting capability. [Ref. 1:Part III, p. 4]

Savings in logistics dollars must be achieved through greater operations efficiency and productivity or readiness will continue to suffer.

The United States General Accounting Office (GAO) has identified numerous ways in which DoD can make improvements. Of particular interest in this study are the opportunities in Defense Inventory Management. In 1992, GAO first reported that the DoD culture tended more to:

> ...overbuy items than to manage with just the amount of stock needed [and that] had DoD used effective inventory management and control techniques and modern commercial inventory practices, it would have had lower inventory levels and would have avoided the burden and expense of storing excess inventory. [Ref. 3]

GAO has produced numerous reports since that time that further document the excess and inefficiency in our inventory systems. They have specifically identified numerous best practices found in commercial industry and followed DoD's progress in implementing them. But, as recently as July, 1997, GAO concluded that progress had been slow in this area, commenting that:

> Because of the potential impact improved business practices would have on DoD inventory levels, operating costs and the repair of weapon systems and component parts, we believe *DoD must be more aggressive* in expanding the use of new management techniques for these items. (emphasis added)[Ref. 4:p. 2]

These findings have been corroborated in numerous other studies. A documented briefing for the Commission on Roles and Missions of the Armed Forces prepared by

RAND Research in support of the National Defense Research Institute summarized the current situation as a

> ...mass logistics paradigm ... [that] has emphasized three mechanisms for providing logistics support: (1) functional bureaucracies ... (2) large inventories, and (3) special management actions.... These mechanisms are inefficient, often ineffective, and not well suited to provide the responsiveness and flexibility required in future military logistics operations.[Ref. 5:p. vi]

## B. WHERE WE WANT TO GO

The vision of future military operations and the logistics operations required to support them has been expressed by DoD and the component services in a series of strategic planning documents. The cornerstone document is the CJCS Joint Vision 2010. Building on that document is the Department of Defense Logistics Strategic Plan (LSP).

According to the LSP, the mission of the logistics system is "to provide responsive support to ensure readiness and sustainability for the Total Force in both peace and war." It will provide reliable, flexible, cost-effective and prompt logistics support, information and services to the warfighters as well as achieve a lean infrastructure. It will meet this vision through, among other things, process reengineering. The LSP highlights readiness as a primary performance measure. This readiness focus is revealed in its first two guiding principles.

- Weapon system availability and material readiness at unit level are of paramount importance.
- The cost and "footprint" of logistics support must be reduced substantially without reducing readiness.[Ref 6]

## C. HOW WE'RE TRYING TO GET THERE

Not surprisingly, the Army Logistic Vision 2010 describes a single logistics system spanning the continuum from tactical, through operational and strategic levels. To implement that vision and the LSP, the Army Strategic Logistics Plan is the management plan the Army is using to guide its logistics operations into the next century. It translates the strategic vision into specific executable objectives, strategies and initiatives. This document, first created in 1995, originally contained 140 separate initiatives. Taken together, these initiatives attempt to shift the Army's logistics paradigm to one of Focused Logistics, the fusion of logistics, information and transportation technologies to provide rapid response and sustainment across the battlefield.[Ref. 7; Ref. 8]

Many of the initiatives outlined in the Army Strategic Logistics Plan have been repackaged into a new term that describes the paradigm shift as the Revolution in Military Logistics (RML) in deference to the ongoing Revolution in Military Affairs (RMA). Most of the RML initiatives seek to leverage information technology, a fundamental characteristic of RMA, as the key enabler of process improvement. Some of the major initiatives in RML are those such as: Logistics Internet, In-Transit Visibility, Total Asset Visibility, Battlefield Distribution and Velocity Management.[Ref. 9]

The Velocity Management concept is the Army leadership's framework for improving logistics performance. It is focused on developing and implementing specific process improvements to achieve the Army's goal of sustaining readiness with reduced inventory levels.[Ref. 10] The Commander, Combined Arms Support Command, is the

Army Executive Agent for Velocity Management (VM). The VM working group is the lead activity responsible for implementing change. This group is organized in several Process Improvement Teams working in partnership with RAND Corporation and various field activities. The teams pertinent to this study are those tasked to achieve Order Ship Time Reduction, Repair Cycle Time Reduction and to improve the Stockage Determination Process.

## D. WHY IT MIGHT NOT WORK

Undoubtedly, many of the initiatives of VM have already had and will continue to have a positive impact on the future logistics capability of the Army. However, the ultimate potential of VM may be limited, particularly in the area of inventory management, for two key reasons. The first reason is a lack of a systems approach and the second is the regulatory framework within which the various initiatives are being implemented.

### 1. A Systems View is Essential

Readiness is a holistic outcome measurement. It is dependant on a myriad of interdependent processes. But, the parallel pursuit of numerous initiatives simultaneously is evidence of a dogmatic, divide and conquer approach to problem solving. While a perfectly legitimate process, the outcome can be expected to be sub-optimal. Optimizing each of the parts does not equal optimizing the whole. Focusing on the separate pieces of the supply chain and using technology to improve efficiency in them is intuitively appealing. However, disregarding the interactive nature of supply chains, ignoring

impacts elsewhere in the system, can yield unintended results. Consequently, system efficiency and overall effectiveness can suffer. In particular, decisions regarding the breadth, depth and placement of stock have a direct impact on both Order Ship Time and Repair Cycle Time. Only when considered as an integrated system can their impact on readiness be evaluated.

The verity of this phenomenon has already surfaced in some of the field tests that have been conducted. One example is the PLL Elimination Test conducted in 1996 by the Army Material Systems Analysis Activity (AMSAA) for U.S. Forces Command (FORSCOM). The purpose of the test was to determine the feasibility and readiness impact of eliminating unit PLL stockage in lieu of rapid and responsive repair parts policies, procedures and systems in a peacetime environment to determine the viability in wartime operations. By direction, test unit PLL's were containerized and not made available. All unit requests for PLL parts were submitted to the supporting supply activity as needed. However, no adjustments to the supporting stocks were made. Readiness predictably suffered. But, it is reasonable to infer that in actuality, under current policy rules, the increased accumulation of demands on the ASL resulting from PLL elimination would eventually have an effect on its composition, mobility and effectiveness over time.[Ref. 11; Ref. 12] Even though some valuable information was obtained from this and similar tests, design factors constrained the analyses and thus limited the conclusions that could be drawn about the validity of the PLL Elimination concept. Consequently, by

not evaluating the reduction of retail stockage points from a systems perspective, a potentially viable concept is no longer being considered.

### 2. Inventory Policy Constrains Supply Effectiveness

Inventory policy is necessary to guide the processes through which maintaining stock achieves readiness requirements. It forms the basis on which the decision support algorithms for all of our Logistics Information Systems (LIS) were created.

The Army's retail inventory model is outlined in AR 710-2, *Supply Policy Below Wholesale Level* and associated documents. For operational units, it is a demand-based, order point, order up to quantity model. Stockage selection is "hit-based"and depth is a function of Operating Level, Order-Ship-Time Level and Safety Stock. The add/retain criteria and stockage levels vary according to stock location.[Ref. 13:Sect. III, pp. 36-38] As compared to more modern inventory models, this model is relatively unsophisticated, inflexible and not directly tied to readiness.[Ref. 14] It is, however, the regulatory framework within which our complex, multi-level retail supply chain exists. It is a fundamental constraint to our ability to achieve a true revolution in military logistics. The model, its use, effects on the supply chain and consequences are described more fully in the following chapter.

## III. ANALYSIS OF CURRENT RETAIL INVENTORY POLICY

This chapter provides a brief overview of the Army's retail inventory system that supports operational forces. The discussion focuses on the process to determine the range and depth of Authorized Stockage Lists (ASLs) at accountable Class IX (Repair Parts) Supply Support Activities (SSAs). ASL *range* is the number of different lines stocked in the ASL. ASL *depth* is the quantity of a single line stocked on an ASL.

In the following sections, we discuss the retail supply support organizational structure, relevant policies, both theoretical and as applied in retail logistics information systems (LIS). We discuss some effects of current policy on inventory levels, costs, supply material availability and readiness. In the last section we discuss current trends in inventory policy resulting from Stockage Determination Process Improvement Team initiatives.

### A. ORGANIZATIONAL STRUCTURE

The Army inventory system consists of multiple echelons, or levels. The *Retail* level is that below the NICP/Depot *Wholesale* level.

> "Retail level stockage generally is oriented toward attaining maximum operational readiness of support[ed] units, and therefore it is based on demand or item essentiality. Installation supply and maintenance activities, direct support organizations, and general support units (GSUs) usually are engaged in retail level supply support." [Ref. 15]

As implied, within the retail level there exist multiple echelons as well. In most cases, field units operate in a three echelon retail system with Organizational Units (motor pools), Direct Support Units (DS supply and maintenance activities) and General Support Units (GS repair parts companies, GS maintenance activities and some installation maintenance activities). The pivotal echelon at the retail level is the Direct Support (DS) level at which a support unit interfaces with customer units. A Direct Support Unit (DSU) may consist of a maintenance activity, a supply activity or both depending on the type of organization.

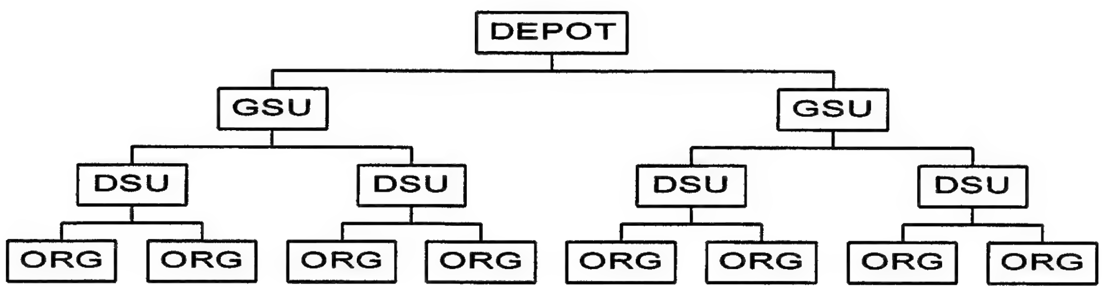



Figure 1. Example of a four echelon system with three retail levels below a wholesale depot.

The mission of a Class IX SSA is to provide repair parts to its various customer units, normally several organizational level maintenance activities and one or more intermediate maintenance activities. Each of these customers retains an authorized stockage of repair parts at its echelon. These unit level inventories are called Prescribed Load Lists (PLL's) at the organizational level and Shop Stock Lists/Bench Stock Lists

(SSL's/BSL's) at the support maintenance level. The SSA is led by an Accountable Officer, normally a commissioned or warrant officer who is responsible and accountable for management of the inventory.

To accomplish its mission the SSA is set up, by doctrine, in three basic sections: the Stock Control section, the Receipt, Storage and Issue section, and the Repairable Exchange Section (In practice, the latter two sections are most often task-organized to perform the various warehousing and materials handling functions). The Stock Control (SC) section performs customer service, order processing, stock accounting, and inventory management functions for the SSA.

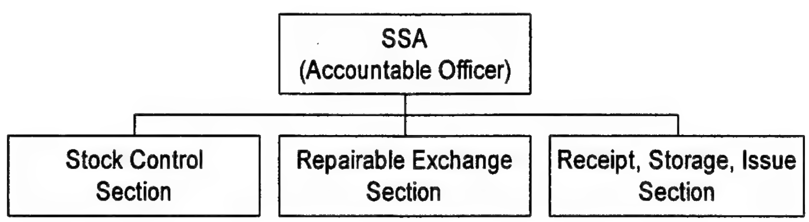



Figure 2. SSA Organization.

One of the primary inventory management functions of the Accountable Officer and the stock control section is the execution of the stockage determination and replenishment processes. These processes most directly influence the adequacy of the inventory in fulfilling its purpose of satisfying the readiness demands of the customer units. Consequently, these are critical processes that, in large part, determine the ultimate success or failure of the SSA, the Accountable Officer and subordinate sections.

## B. POLICY GUIDANCE

There are two primary documents that provide policy and implementation guidance for the stockage determination and replenishment processes in Army retail inventory management. These cornerstone documents are AR 710-2, *Supply Policy Below Wholesale Level* and DA PAM 710-2-2, *Supply Support Activity System Manual Procedures.*

### 1. Range

Essentiality is a primary consideration for stockage selection. Accordingly, repair parts selected for stockage are restricted to only mission essential items. Each item selected for stockage must either be Demand Supported (annotated in the stock record account as Stockage List Code SLC Q), Mandatory (SLC P) or Command Directed (SLC M). SLC-P are non-demand supported items stocked to support newly introduced end items that are still within the demand development period and have not yet qualified to be stocked as SLC-Q. SLC-M are non-demand supported items that are seasonal and combat essential and do not qualify as SLC-Q. (In practice, these items have been all but eliminated from active inventories due to fiscal constraints.) The vast majority of stocked lines are SLC-Q and are the focus of this discussion.

Stockage of an SLC-Q item is based upon actual recurring demands in a 360-day control period. A recurring demand is a periodic or repetitive request for material for immediate use or stock replenishment. Note that a demand is defined as the request, or

requisition, not the quantity of the item required. Because most demands are recurring, when there is doubt as to the nature of the demand, it is considered to be recurring.

Items may be added to an ASL as SLC-Q based on achieving at least nine demands within a control period. Previously stocked SLC-Q items failing to achieve at least three demands in the most recent control period are deleted from the ASL. These stockage requirements are known as the *Add/Retain Criteria*.

| CATEGORIES | SLC | CRITERIA |
|---|---|---|
| Demand Supported | Q | 9 recurring demands in 360 days to add, 3 recurring demands in 360 days to retain |
| Mandatory | P | Initial provisioning requirements during the demand development period |
| Command Directed | M | Minimum level to meet readiness goals or seasonal requirements |

Table 1. ASL stock categories and add/retain criteria, after Ref. 13.

### 2. Depth

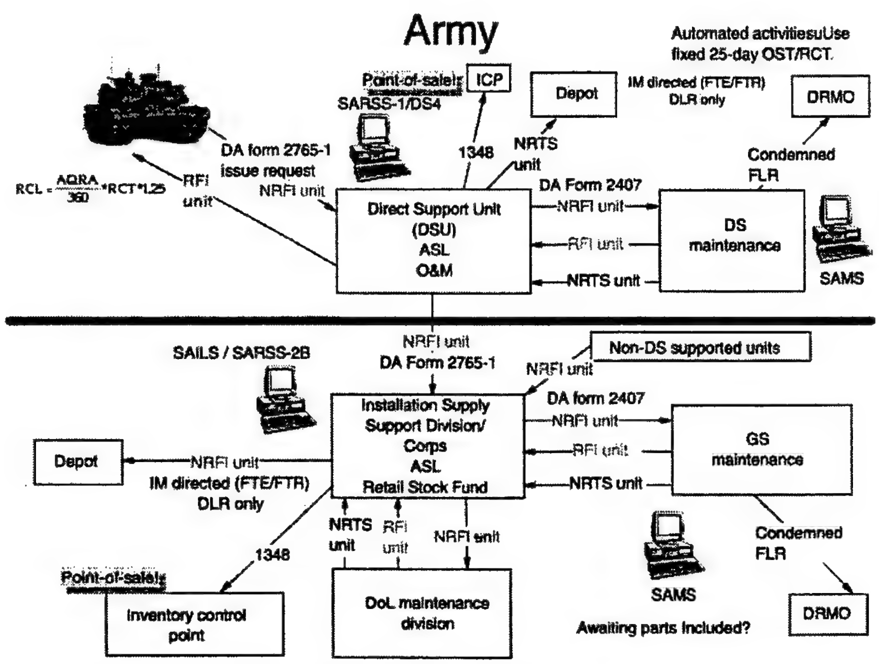
The stockage level of an item on an ASL is known as its Requisitioning Objective (RO) and is the maximum quantity authorized to be on hand or on order at any time. RO computations are made in a days of supply (DOS) or economic order quantity (EOQ). The regulation specifies that the DOS method will be used by all Modified Table of Organization and Equipment (MTOE) SSAs (divisional and non-divisional type operational units) and that ROs will be computed at least semiannually or when the on-hand balance equals zero. The EOQ method is specified only for Table of Distribution and Allowances (installation support type, non-operational units) and GS MTOE SSAs.

The DOS RO consists of an operating level (OL), order ship time (OST) level, and a safety level (SL). The reorder point (ROP) is the sum of the OST level and the SL. For CONUS SSAs, the OL is 15 days, the SL is 5 days and the OST is the average elapsed time from requisition to receipt at the SSA (automated systems default to 25 days).

The DOS RO computation differs for repairables and is dependent on where the failed item is repaired. When a repairable component fails, it is removed from the end item and turned in to the supporting SSA as a Not Ready For Issue (NRFI) asset. At this time repair cycle time (RCT) begins. The customer requests a new component and is satisfied from Ready For Issue (RFI) assets at that point of sale. Otherwise, a due-in-from-maintenance backorder is posted. Depending on the authorized level of repair for the component, the NRFI asset is forwarded to the appropriate maintenance activity either DS, GS/Installation or Depot. The maintenance activity may or may not be local. If the component is condemned at any level, it is a washout and is disposed of accordingly. RCT ends when the repaired component is received into the SSA stock record account as an RFI asset. Figure 3 illustrates the intermediate level repair process and its interaction with the retail supply system.[Ref. 13:pp. 36-41; Ref. 15]

The RO for material repaired locally consists of a repair cycle level (RCL), OL, OST level and SL. The RCL is based on the average quantity of repairs completed annually. The OL, OST level and SL are based on washouts only. The ROP is the sum of the RCL, OST level and SL. The RO is the ROP plus the OL. For material not

repaired locally, the RO is the same as consumables except that the OL is computed by EOQ (order cost = $4.50, holding cost = .40 x unit cost). [Ref. 16; Ref. 17: Chp. 4, pp. 18-22] The information above and relevant equations are summarized in Table 2 and Figure 4.[Ref. 15; Ref 17: Appx G, pp. 264-265]




*Note:* IM = item manager; FTE = report of excess; FTR = report of excess response ; DLR = depot-level reparable; FLR = field-level reparable; NRFI = not ready for issue; RFI = ready for issue; DoL = director of logistics; DA = Department of the Army ; NRTS = not reparable this station; RCL = repair cycle level; QRA = average quantity repaired annually; RCT = repair cycle time.

Figure 3. Army retail logistics system, from Ref. 15

| FACTOR | FORMULA (ITEM REPAIRED LOCALLY) | FORMULA (ITEM NOT REPAIRED LOCALLY) |
|---|---|---|
| OL | EOQ fourmula using average daily washout quantity | average daily demand x 15 days (CONUS) |
| RCL | 1.25 x RCT x average quantity repaired daily | N/A |
| OST | average daily washout quantity x average OST days | average daily demand x average OST days |
| SL | average daily washout quantity x 5 days | average daily demand x 5 days (CONUS) |

Table 2. Factors used to calculate Requisition Objective (RO), after Ref. 15

$$ROQ = \left( \frac{OLD + SLD + OSTD}{360} \right) \times QDCP$$

Equation 1. Requisitioning Objective Quantity Calculation (DOS method)

$$ROPQ = \left( \frac{SLD + OSTD}{OLD + SLD + OSTD} \right) \times ROQ$$

Equation 2. Reorder Point Quantity Calculation (DOS method)

$$OLQ = \sqrt{2DA/IC}$$

Equation 3. Operating Level Quantity Calculation (EOQ method)

$$ROPQ = \left( \frac{D}{360} \right) \times (SLD + OSTD)$$

Equation 4. Reorder Point Quantity Calculation (EOQ method)

$$RCL = \left( \frac{AQRA}{360} \right) \times RCT \times 1.25$$

Equation 5. Repair Cycle Level Calculation

LEGEND:

OLD = Operating Level Days
OSTD = Order Shipping Time Days
QDCP = Quantity Demanded in the Control Period
SLD = Safety Level Days
D = Average Annual Demand
A = Order Cost (set at $4.50 by HQDA)
I = Annual Variable Holding Cost in % of Unit Price (set at 40% by HQDA)
C = Unit Price of the Item
AQRA = Average Quantity Repaired Annually
RCT = Repair Cycle Time

Figure 4. Stockage Level Computations, after Ref 17, Appx. G

## C. RETAIL LOGISTICS INFORMATION SYSTEMS (LIS)

The cornerstone of Army retail LIS is the Standard Army Retail Supply System – Objective (SARSS-O). In the last stages of fielding in the active force, SARSS-O is the system of LISs that perform all automated retail inventory management functions above

organizational level. Its major improvement over the displaced LIS is its local lateral search capability which increases asset availability through "virtual consolidation."

The methodologies for stockage determination and level computation, however, are still based on AR 710-2 as described above. The inputs, logic, and outputs from the demand analysis process (which recommends changes in ASL range and depth based on demand history) is almost identical to that of the legacy system.[Ref. 18]

## D. RETAIL SUPPLY PERFORMANCE MEASURES

There are three common measures of performance related to retail supply material availability that are of interest in following discussions. They are gross effectiveness, net effectiveness and accommodation. Of these, the Army currently only uses a net effectiveness measure called Demand Satisfaction. It is defined as the percentage of demands completely filled from stock of the total demands for stocked items (# demands for ASL items completely filled divided by # demands for ASL items x 100). This metric indicates the effectiveness of the ASL stock *as selected.* It is a measure of the adequacy of ASL depth.

Conversely, the Army has in the past also used demand accommodation as a performance metric. It is defined as the percentage of demands for stocked items of the total number of demands (# demands for ASL items divided by # demands for all items x 100), a measure of ASL range. Thus, accommodation indicates the effectiveness of the stock selection process and is useful in this discussion. Although not normally used as a performance metric, fill rate is how the customer measures the overall effectiveness of

retail supply support. A measure of gross effectiveness, it is the percentage of demands completely filled from stock of the total number of demands (# demands filled divided by # demands for all items x 100).

## E. EFFECTS OF CURRENT POLICY

The existing retail inventory policy successfully supported Army forces through the end of the Cold War. But, as indicated in Chapter II, it is no longer sufficient to meet the demands of the many stakeholders in today's dynamic environment. Current policy has a great impact on the nature, characteristics and effectiveness of stocks held at the retail level.

In this section, we document a few effects and consequences of five critical elements of the Army's current retail inventory policy. These policy elements are 1) the use of add/retain criteria in the stock selection process, 2) the determination of requisitioning objectives and reorder points, 3) the ASL review process, 4) the definition of demand, and 5) ASL performance measures.

### 1. Policy Element: Add/Retain Criteria

EFFECTS: Two effects of using add/retain criteria as the method for stock selection are 1) the method fails to consider the cost of an item, and 2) the method fails to select many parts needed for readiness.

Under the existing system, inventory cost is a deterministic outcome based on demand. Item cost is not considered at all in the stock selection process. An item is selected for stockage based on frequency of demand alone, without consideration of

price, quantity demanded, weight, cube, lead time (OST or RCT) or other defining characteristic. Thus, as with investment cost, other costs such as stockout, mobility and expedited shipping of non-stocked items are equally deterministic in the current process.

Although common in military applications, the "hit-based" nature of the add/retain criteria make them particularly ineffective for retail stock selection where often the customer's opportunity cost of a non-stocked line is ostensibly measured in Non-Mission Capable Supply (NMCS) days equal to the OST. The degree to which add/retain criteria impact the stockage selection process is demonstrated in a recent study performed by Army Material Systems Analysis Activity (AMSAA) at the 3rd Infantry Division during Calendar Year 1996. The results were presented as part of a briefing to the Army Deputy Chief of Staff for Logistics (DCSLOG) on 30 July, 1997. The study found that for essential parts requested, 79% of the unique line items had fewer than nine demands and would not have qualified for stocking; 51% of the lines had fewer than three demands and would not have qualified for retention. More strikingly, nearly half of the 38,364 NMCS and anticipated NMCS demands were requested fewer than three times and would not qualify for stocking or retention.[Ref. 19]

CONSEQUENCES: At least three consequences resulting from these effects are that 1) determined needs can exceed available budgets, 2) readiness is reduced and 3) incentives are created for gaming.

Requirements resulting from the stock selection process can often exceed the available budget for additions (even after considering credit for deletions). Consequently,

these requirements may go unpurchased negating the effort to shape the ASL more toward customer needs.

Further, it is evident from the 3rd ID study that the stockage selection process does not inherently support many of a customer's requirements for critical items. The results of the study indicate that the range of stock selected by AR 710-2 rules does not well accommodate the range of customer requirements for NMCS parts. If an item is not stocked at the supporting SSA, then the item must be passed to the higher source of supply and backordered to the customer. Each day the customer waits for a NMCS part is a day of non-availability which degrades that customer's readiness.

Consequently, astute customer unit commanders and maintenance managers then have a strong incentive to "game" the process to use the structure of the system to their advantage. For example, if customers want a particular part stocked in the supporting ASL, they artificially reduce the quantity demanded per requisition, or order more than they immediately require, in order to meet the add/retain criteria.

**2. Policy Element: RO/ROP Calculation**

EFFECTS: Two effects of the depth calculation and replenishment process are 1) cost is minimized despite potential negative impact on readiness and 2) part order frequency does not match consumption rate.

Unlike range selection, some costs are included in the depth calculations that use EOQ. The current methodology uses fixed rates of order and holding costs, regardless of actual costs, item characteristics or location. Although EOQ is a robust model for

minimizing cost, it is more useful in profit-oriented environment vice a military environment where operational availability is a vital concern.

Under a fixed reorder point system, the timing of replenishment does not coincide with part usage, unlike a one-for-one type replenishment system. Part usage rates vary at the customer unit level due to the nature of the demand itself and changing OPTEMPO. Replenishment rates depend largely on where the reorder point is set (the closer the ROP is to the RO, the greater the frequency of demand generated) as well as availability of funds and a myriad of other potential factors. The result is that the customer's replenishment pattern does not reflect the actual consumption pattern. This effect, when compounded across several customer units, results in a very distorted view of customer requirements at the support level.

CONSEQUENCES: At least two consequences resulting from these effects are that 1) significant adjustments often occur in the review process, and 2) increased variability is introduced into the replenishment process.

Because EOQ is a cost-minimizing function, this method will tend to stock less of more expensive items without consideration of the item's impact on readiness. This tendency is the more so with the conservatively high estimate of holding cost factor (.40) the Army uses in its EOQ calculations. This method can yield stock levels insufficient to satisfy a commander's perceived needs. Consequently depth of these more expensive lines is often increased during the review process as will be shown in a later section.

As replenishment demands are combined with higher priority non-replenishment type demands and all demands for items are consolidated across many customers at the SSA, the picture of actual consumption gets further distorted. When these demands are forwarded up the supply chain, the inherent variability propagates, only with greater amplitude. This phenomenon, called the "bullwhip effect," has recently been observed and quantified in the private sector. The consequence of the effect is that greater variability directly influences safety stock levels at all echelons, thereby increasing inventory investment.[Ref. 20]

### 3. Policy Element: ASL Review Process

EFFECTS: Two effects of the ASL Review process are 1) increased stock churn and 2) subjective judgments are introduced.

ASL reviews are currently conducted at least twice per year. As was seen in the 3rd ID study, many items that may have previously qualified for stock, do not qualify for retention upon subsequent review. A surge in demand could then requalify the item for stock upon further review. This scenario is not uncommon in the author's experience. On more than one occasion, an item was received into the warehouse as a "newly" added item that still had the turn-in document generated six months earlier, by the same warehouse, due to the item being deleted from stock during the previous review. As the frequency of review increases, this turbulence, or *churn* of stock, increases.

In the 3rd ID study, the actual performance of a purely SARSS-O generated ASL on essential requisitions over CY 1996 was:

| | |
|---|---|
| Demand Accommodation | 79% |
| Demand Satisfaction* | 75% |
| Fill Rate | 59% |

* Note that the DA Goal for demand satisfaction is 75% with a management level of 70%-80%.
[Ref. 13: Chp. I, Sect. III; Ref. 19]

ASLs built to strict AR 710-2 policy can meet stated Army supply performance goals. Almost always, however, recommended lists are subjectively changed during the ASL review process to try to improve ASL performance and to hedge against unforecasted increases in demand.

CONSEQUENCES: At least two consequences resulting from these effects are that 1) increased handling costs are incurred and 2) ASLs in use vary greatly from AR 710-2 guidelines.

Stock churn generates additional costs in several ways. The most immediate cost is the purchase of lines added to the ASL. However, other costs are significant as well. These costs include redistribution, materials handling, manpower and others.

The degree to which ASLs are changed from AR 710-2 recommendations can be dramatic, particularly in the dollar value of RO. For example, in January 1996, the 3rd ID SARSS-O recommended ASL for essential line items based on AR 710-2 was 5,604 lines at a cost of $28.6 million. The actual ASL retained on the ground had 5,424 lines with a value of $80.3 million.[Ref. 19]

### 4. Policy Element: Definition of Demand

EFFECTS: Two effects of the demand definition are 1) distortion of data input into the stock selection process, and 2) distortion of output performance measures.

According to AR 710-2, a demand equates to a requisition and not the quantity required. While easy to count, track and analyze, this fundamental concept of demand has several negative effects. Among them, this definition of demand exacerbates the effects described earlier in the add/retain criteria discussion by masking the "true" nature of the demand. The quantity of an item a customer demands per requisition may depend on several factors. However, the automated demand analysis process will not consider an item for addition if it does not meet the add criteria, regardless of the quantity demanded. Likewise, it will delete an item not meeting retain criteria regardless of the quantity demanded. An item with two demands for a total quantity of forty gets the same recommendation for deletion as does an item with two demands for a total quantity of two.

The definition of demand also distorts the calculation of demand-based supply performance measures. The current calculation method can yield misleading results. For example, a customer may request five each of five different items, four of which are stocked lines. Suppose two of the ASL requests were completely filled from stock and the two others partially filled (4 each) with the remaining quantities and the request for the non-stocked line backordered. The following results are obtained:

| | |
|---|---|
| Demand Accommodation (request-based) | 80% |
| Demand Satisfaction (request-based) | 50% |
| Fill Rate (request-based) | 40% |

However, the customer is often concerned only with the number of parts received of the number requested. On a quantity basis, net and gross effectiveness are dramatically different as seen below:

| | |
|---|---|
| Demand Accommodation (quantity-based) | 80% |
| Demand Satisfaction (quantity-based) | 90% |
| Fill Rate (quantity-based) | 72% |

CONSEQUENCES: At least two consequences resulting from these effects are that 1) subjective judgments are required during the ASL review process to adjust for the quantity demanded, and 2) lack of precision in performance measures limit their utility and can cause misinterpretation.

Because of the disparity in the number of demands and the quantity demanded for each item, a diligent accountable officer must still review each line's demand history manually despite the recommendations made during the automated process. This manual review often can result in subjective decisions to override the AR 710-2 recommendations for additions and deletions.

The example of supply performance results described above demonstrates the difficulty these measures have in showing the benefit the ASL provides customers because of the request-based, vice quantity-based, definition of demand. The imprecise

nature of these performance measurements, as currently calculated, can cause leaders to misinterpret the effectiveness of their stockage decisions. This misinterpretation can lead to needlessly increasing stock levels if, as in the example, perceived (demand-based) performance is less than actual (quantity-based) performance.

### 5. Policy Element: ASL Performance Measures

EFFECTS: Two effects of the current metrics are 1) incentives focus on operations efficiency not effectiveness of stock determination and 2) incentives are created to increase depth at the expense of range.

Most of the ASL performance measures listed in Table 1-2, AR 710-2, focus on the efficient management of the inventory once its composition is determined. Requisition processing time, receipt processing time, zero balance rates and inventory accuracy, among others, reward efficiency. Demand satisfaction is the only supply effectiveness metric used. But, as previously noted, demand satisfaction is only a measure of the adequacy of depth.

Because demand satisfaction is measured, an incentive is created to ensure adequate depth is carried to satisfy demands. This incentive can lead to decisions to increase the depth of certain lines in lieu of the addition of new lines and corresponding acceptance of increased risk of an unsatisfied demand. The *zero balance rate with dues out* metric also creates a strong incentive to increase range. Although an RO of one and an ROP of zero is a perfectly valid stock level recommendation, it will almost invariably be increased to two and one respectively (regardless of cost) to minimize the risk of

stockout and the corresponding increase in zero balance rate. The influence of this incentive increases as the range of stock decreases due to the greater marginal impact of even one stockout. This rational, yet errant, behavior has often been personally observed by the author *in himself* as well as in others.

CONSEQUENCES: At least two consequences resulting from these effects are that 1) ASL costs increase, 2) incentives are not aligned to support customer readiness.

It is easy to surmise that increasing depth can lead to increasing costs of an ASL. The 3rd ID study dramatically shows the extent to which the review process can increase the cost of an ASL with little impact on its supply effectiveness. Table 3 compares the composition and performance (on essential, NMCS requisitions) of a SARSS-O recommended ASL with that of the actual ASL carried by the division.

| MEASURE | SARSS-O ASL | ACTUAL ASL |
|---|---|---|
| Size | 5,604 Lines | 5,424 Lines |
| Value | $28.6 Million | $80.3 Million |
| Demand Accommodation | 86% | 76% |
| Demand Satisfaction | 79% | 82% |
| Fill Rate | 68% | 62% |

Table 3. 3rd ID Performance Summary, Jan-Dec, 1996, from Ref. 19

As modified during the ASL Review process, the actual ASL had 180 fewer lines but cost $51.7 million more. This suggests that demand supported range was traded for increased depth of higher value parts. The performance of the ASLs is consistent with

that conclusion as the modified ASL achieved greater satisfaction (a measure of depth) with less accommodation (a measure of range). However, fill rate (the customer's performance measure) decreased from 68% to 62%, hardly a positive return on investment.

But, commanders and inventory managers may not necessarily agree since their key performance metrics, such as demand satisfaction and ASL zero balance rates, provided adequate incentive to carry the greater depth despite its increased cost and negative impact on readiness. Gross effectiveness, an output measure more objective and more closely aligned to customer readiness, had not normally been measured thus making easier the decision to sacrifice range.

## F. SUMMARY

Each of the preceding sections have demonstrated the decoupled nature of the Army retail supply system with respect to readiness. Under current policy, readiness requirements and item costs are not inputs into the stockage determination process. Equipment availability is an output from the process for which its measurement is not directly attributable to the performance of the supply system. Similarly, inventory investment is an output that is not directly attributable to the amount of readiness purchased with those dollars.

One might question how units have historically sustained high equipment readiness rates despite correspondingly low gross supply effectiveness rates. We believe that improvements in distribution processes resulting from OST reduction efforts deserve

some credit. However, the author's experience as a unit commander suggests that readiness is achieved, in large part, by extraordinary actions such as using alternate sources of supply, controlled substitution, and command intervention; rather than as a result of effective supply policy. This suggestion is consistent with Representative Spence's observation of what he called the "desperate shell game" being played by commanders to maintain readiness.

The complexity of even these few specifically highlighted effects of current policy is perhaps daunting. The cumulative effect however, may best be summarized in a statement made by an officer who had recently guided his division through its conversion to SARSS-O. In the Report of Proceedings published from the most recent Velocity Group meeting held on September 30, 1997, he was quoted as commenting to the DCSLOG that although his division had achieved a one-time cost reduction of $9.9 million:

> ...the division did not buy a lot of the demand supported, SARSS-O recommended stockage above $1500 because it could not afford to...that they bought about eighty percent of the SARSS-O recommendations, and *that ought to be enough to maintain readiness.* (emphasis added) [Ref. 21]

## G. TRENDS IN RETAIL SUPPLY POLICY

The Army has recognized the need for policy change. The Logistics Integration Agency, under the DCSLOG, is the proponent for AR 710-2. The newest version is scheduled to be published in the 2nd quarter Fiscal Year 1998. This version has some significant changes. For the first time, Readiness Based Sparing is introduced as an

additional method of computing the requisitioning objective. Items selected for stockage using RBS are to use Stockage List Code M.[Ref. 22]

The Velocity Management Stockage Determination Process Improvement Team is in the process of developing requirements and a strategy for future policy changes. The near, mid and long-term policy recommendations were briefed to the DCSLOG in April 1997.

### 1. Near-Term and Mid-Term Recommendations

Near-term recommendations have been or will be included in the proposed changes to the current version of AR 710-2. No change is recommended in the current add/retain criteria or depth calculation methodologies. Two additional recommendations were made. The first recommendation was that ASL reviews should be conducted at least once per year (instead of twice). The second near-term recommendation was that the definition of SLC-M should be changed to reflect that it now does not mean only non-demand supported since the inclusion of RBS as a newly authorized alternative method of stock selection.

The team had two primary recommendations in the mid- term: one that dealt with range and one that dealt with depth. The first recommendation was to analyze the potential benefits associated with setting add/retain criteria levels for discrete dollar value levels (for example, 3/1 for items < \$100, 6/2 for items > \$100 but < \$1000, 9/3 for items > \$1000) with the intent to "broaden the breadth of inexpensive lines". The second recommendation was to analyze the use of EOQ in the depth calculations for all items

and begin to take into account demand and lead time variability in the calculation of safety levels.[Ref. 23]

These recommendations, however, are largely only incremental changes to the existing policy. They represent continued attempts to reduce cost, and still do not address readiness directly. The implementation of these recommendations alone will not mitigate many of the specific effects previously described. Moreover, these recommendations may have unintended effects with perhaps even more severe consequences.

Discrete ranges of add/retain criteria will tend to select more lower dollar items and deselect higher dollar items. However, the selection of the add/retain quantities and dollar value ranges are arbitrary and do not facilitate a measurable estimate of their impact on readiness. Accordingly, it is reasonable to expect that behavior in the ASL review process would not change. Therefore, the net effect on actual stock carried by units under that proposed policy is questionable.

Using EOQ for all items may be preferable to the DOS method, but the consequences of using an EOQ policy (such as arbitrarily set order and holding costs, no link to readiness, etc.) remain. Incorporation of actual variability data may reduce calculated safety levels but only if currently used constant demand and lead time assumptions are conservatively high.[Ref. 23]

### 2. Long-Term Recommendations

The long-term recommendations begin to address some of the concerns in this study. The essence of the recommendation is to "develop a decision support system that

allows what-if modeling" and that enables commanders to "vary readiness goals and establish metrics on a weapon system basis".[Ref. 23] Such a system can exist using an RBS inventory model as presented in the following chapter.

# IV. THEORETICAL BASIS FOR A RBS RETAIL INVENTORY POLICY

## A. WHY READINESS BASED MODELS?

### 1. The Item Approach

Traditional inventory models, like the current Army model, use an *item approach* as alluded earlier. In an item approach, a decision to stock a given item is made independently of decisions made to stock other items. Recall that with add/retain criteria, an item is selected for stock based on demand within a control period and no other consideration. Similarly, a decision on how much of the item to stock is determined by simple formulas that balance the costs of ordering, holding and stockout *for that item* and is independent of other considerations.

The item approach has served well a retail industry that provides largely consumable items for customers. If an item is not stocked, the customer can either go elsewhere to buy the item or can choose to wait to receive the item on backorder. Military customers differ in that their systems must be ready nearly all the time. It can be shown that for their complex, highly technological systems, repairable items are far more important to system availability than consumable items.[Ref. 24: Chapter 1] Intuitively, that conclusion is consistent with Army maintenance practices where the majority of tasks at the organizational and direct support levels are replacement of major components versus diagnosis and repair. In this context, a failed part that generates a requirement usually means that a system is not available to perform its assigned mission. Thus, the

cost of a stockout to a military customer is measured in terms of readiness and higher probability of mission failure.

The negative consequences detailed in the previous chapter are inherent disadvantages of an item approach where weapon system availability and investment cost to support a weapon system are "uncontrolled outputs" of the item decisions. Suppose the accumulation of item decisions yields an unacceptably low availability of a supported fleet or that the computed investment exceeds the budget available; what alternatives are left to the decisionmaker? As demonstrated, managers are left to making subjective adjustments based on experience, the effectiveness of which is unknown.

### 2. The System Approach

The essence of a *system approach* to inventory modeling is to determine the system cost-effectiveness of stock decisions. Unlike the item approach, the system approach uses weapon system availability and weapon system support investments as input parameters to the decisionmaking process. The system approach is able to answer questions like, "What do I need to carry to ensure that at least 90% of my tanks won't be unavailable due to a lack of spare parts?" "How much will it cost me to raise my confidence level to 95% and which additional parts are required?"

The system approach answers these questions by presenting the commander with a weapon system availability-cost curve like the one shown in Figure 5. The curve represents the dollar cost of incremental change in availability. Points above the curve are not attainable and points below the curve represent an inefficient allocation of

resources. Note that the curve reflects diminishing returns in that, at successive readiness levels, the incremental cost of additional availability increases. Thus, the commander can choose the efficient mix of stock, represented as a point on the curve, that satisfies availability requirements within budget restrictions.[Ref. 24: Chapter 2]

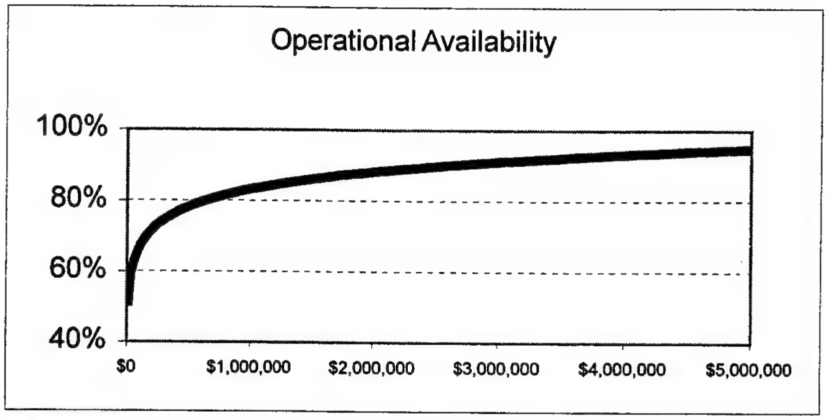



Figure 5. Example of a Weapon System Availability–Cost Curve

### 3. The Difference

Consider the decision to stock two different items, both having the same probability of failure (demand) and the same detrimental impact on the weapon system (essentiality or criticality). One part costs $10 and the other costs $1000. An additional unit of either item yields the same increase in availability but one costs a hundred times more than the other. All other attributes being equal, a commander would chose to stock more of the cheaper item to get more *bang for the buck.*

One might argue that when a weapon system fails, it doesn't matter how much the replacement part costs. It is true that a tank must be made mission capable as quickly as

possible *after* a failure occurs. But, the management challenge is to efficiently allocate a spare parts budget across a group of items *before* any failures occur. It is at that point (i.e. before) that cost must be considered. Obviously, this example is oversimplified, but the system approach does account for an item's relative contribution to readiness as will be shown in the following section.

## B. MODEL DESCRIPTION

### 1. Background

The remainder of this discussion will focus on treatment of repairable components of end items. Compared to consumable items, repairables typically cost more, are demanded less frequently and have longer lead times. Another characteristic of repairables is that they are "memoryless" meaning that the time to the next failure is not dependent on the time since the last failure. The memoryless distribution is the exponential distribution. When the time between failures follows the exponential distribution, then the number of failures expected over any fixed time period is given by the Poisson distribution. Empirical evidence shows that the Poisson distribution provides a reasonable stochastic model to describe the occurrence of failures of most repairable items.[Ref. 24]

### 2. The Single Site Model

The *single site model* demonstrates the mechanisms that are the foundation of RBS methodologies. This model describes the stock selection process at a single base without regard to like decisions at other bases or stock at a depot (higher source of

supply). The model seeks to maximize availability by seeking to minimize the expected number of backorders (EBO) systemwide. It can be shown that minimizing EBO of failed components corresponds to maximizing weapon system availability. The model uses marginal analysis to achieve this goal for any specified budget. In summary, the model adds items to stock that provide the greatest marginal decrease in EBO per unit cost of adding that additional unit to stock. The process is repeated iteratively until the budget is consumed.[Ref. 24: Chapter 2]

With appropriate data, the model can likewise be run against constraints such as mobility instead of budget. For example, it can use marginal analysis to achieve the maximum availability for a given weight or cubic capacity. The model can also be run to achieve a specified weapon system availability goal *at least cost* (weight or cube).

### 3. The Multi-echelon Problem

The single site model, as described above, briefly introduces the mechanics of how a readiness based model works, however, there are several reasons why the need for a multi-echelon inventory model is significant. The first reason is that a multi-echelon model more accurately imitates the complexity of military supply and maintenance systems. Second, as seen in Chapter III, intuition can be unreliable in even relatively simple resource allocation problems. Also, consider demand that might not justify stockage at any given retail point; that same demand, when aggregated, might justify stockage at some central point. Finally, making good decisions at one location while ignoring like decisions at others and those of supporting activities still suboptimizes the

total system. A multi-echelon model optimizes the total system by accounting for the attributes of each activity at each echelon.[Ref. 25]

The Multi-Echelon Technique for Recoverable Item Control (METRIC) is an example of such a multi-echelon inventory model. First developed for the Air Force in 1968, it extends the previous single-site model to handle situations where multiple bases are supported by higher level activities called depots (the terms base and depot are applied generically to facilitate discussion). This technique takes into account demand, probability of repair and repair turnaround time at each of the bases *as well as* repair turnaround time and ship time from a supporting depot to the bases. Using marginal analysis, the technique determines the most cost effective mix of items and the optimal allocation of stock among the depot and bases to maximize weapon system availability.[Ref. 24: Chapter 3]

A variant of the METRIC model can also account for the multi-indentured nature of repairable items. This variant again uses marginal analysis to decide whether it is more cost effective to stock the first-indenture component or stock lower-indentured parts to facilitate the repair of the component. Further variants can also account for other realities such as cannibalization actions and lateral resupply options among bases.

In review, the METRIC model provides a method to optimally determine where to position inventory in a multi- echelon system such as the Army's supply and maintenance system. Acknowledging that selecting a stock level at a base depends on order ship time, depot and base repair rates, and other factors, this model provides a way to measure

inventory savings from improvements in these related processes. This tool would facilitate ongoing and continuous Army efforts in order ship time and repair cycle time reduction by their respective process improvement teams mentioned in earlier chapters.[Ref. 26]

A more detailed summary of rudimentary METRIC theory is provided by the author in the Appendix. The definitive reference for the interested reader is *Optimal Inventory Modeling of Systems, Multi-Echelon Techniques* (John Wiley and Sons, New York, 1992) by Craig C. Sherbrooke of the Logistics Management Institute. Another reference is *Operating Policies for Non-stationary Two-Echelon Inventory Systems for Reparable Items* (AMSAA Special Publication No. 39, May, 1986) by Meyer Kotkin and available through the Defense Technical Information Center (File No. AD-A173 731).

## C. SUCCESSFUL IMPLEMENTATION OF RBS INVENTORY MODELS

### 1. Commercial Industry

The extent to which RBS methodologies are being used in commercial businesses is largely undocumented. Sherbrooke highlights a notable exception. He cites a report by Cohen, et al., that IBM's "Optimizer" has produced excellent results. Their goal was to reduce inventory investment while sustaining a specified high level of service. Their model incorporates over 200,000 part numbers in a four echelon system. The authors reported average inventory investment decreased 20% to 25%, a savings of $250 million, to achieve the same service level.[Ref. 24: Chapter 9]

### 2. U.S. Military

The U.S. Military's association with readiness based methodologies is long. First developed in coordination with the Air Force, it has evolved at different speeds, in different degrees and with different applications among the services. The value of the methodology was recognized and endorsed by the Department of Defense as early as 1982 when Assistant Secretary of Defense Juliano published a memorandum which read, in part:

> The traditional approaches to determining inventory levels and measuring supply performance have been related to the satisfaction of demands for items of supply. Such approaches do not normally identify the degree to which various secondary items contribute to the operational availability of weapon systems. We are now attempting to relate stockage decisions to the effect they have on weapon system readiness. This concept represents a significant departure from traditional supply management in that it shifts the material manager's concern from item-oriented inventory performance to weapon system performance....
>
> I cannot overemphasize the significance of this effort nor the potential magnitude of the changes to our material management policies and processes that it offers. It will be a long-range effort, and...I solicit your full cooperation in this effort to improve logistics support in the Department of Defense.[Ref. 14]

Two years later, in 1984, the Office of the Secretary of Defense's Weapons Systems Management Concept explicitly stated that "all retail requirements determinations could and should eventually be done by RBS methodologies".[Ref. 14] To date, all services have demonstrated some degree of success with numerous models based on RBS theory, though most have been in wholesale applications.

#### *a. Air Force*

The Air Force was the first to embrace the new methodology. In early tests conducted at George AFB in the mid-1960s, the average number of backorders decreased by 44% with an investment 46% less than under the previous method (aircraft availability was not tracked).[Ref. 24] Using daily demand data and actual repair times from the same test period and the same level of investment, the new model would have achieved a 32% higher fill rate with a corresponding 39% reduction in backorders. The Air Force Logistics Command currently uses both METRIC models and multi-indenture, multi-echelon models in various applications. However, unlike the other services, they tend not to use the methods for procurement of initial spares. The Air Force prefers smaller initial buys with larger follow on purchases for which they use their RBS models extensively.

#### *b. Navy*

Since 1980, when the Secretary of the Navy approved the concept for use, the Navy has led the services in incorporating readiness based models in their logistics support processes. The Naval Sea Logistics Center is the lead agency in the Navy for RBS whose stated objective is

> To provide the range/depth/location of spare parts to support required readiness objectives at least cost given the reliability and maintainability characteristics of a system...[in consideration of] all levels of maintenance and all echelons of inventory.

And they have concluded that

> Beginning the RBS analysis early in the acquisition process and continuing through the life cycle of the system can provide a powerful tool for evaluating system performance, planning system improvements and determining cost-effective support requirements.[Ref. 27]

The Navy uses readiness based models at both the wholesale and retail levels, in accordance with DoDINST 5000.2 (February, 1991) and later revisions that state investment in spares should be "related explicitly to system readiness objectives" and based on realistic estimates of demand rates and system utilization. The Navy incorporates RBS, Reliability Block Diagrams and simulation to determine initial spares requirements at the wholesale level.[Ref. 28]

Retail use in the Navy began in 1987 when approval was given to implement RBS for development of Coordinated Shipboard Allowance Lists (roughly equivalent to an ASL for ships) for the Arleigh Burke Guided Missile Destroyer Class.[Ref. 29] In 1993, research by the Center for Naval Analysis (CNA) indicated the Navy could, using RBS, reduce the cost of Aviation Consolidated Allowance Lists – AVCAL - (ASLs to support aircraft on a carrier) without degrading readiness. Over the next year the CNA conducted an "at sea" test of an RBS AVCAL on the airwing from the carrier USS *America*. The results are summarized as follows:

- The RBS AVCAL supported *America*'s airwing as it was designed to do with no loss in readiness at a substantial (26%) cost reduction.

- *America*'s airwing Fully Mission Capable (FMC)rate for the deployment was 69% - 8 points higher than the Chief of Naval Operations Goal.

- *America*'s airwing readiness measures, including FMC, were consistent with those reported by all other carriers deployed within the same time frame that were supported with AVCALs developed under then current demand based methods.[Ref. 29]

These successes have led the Navy to study multi-echelon, multi-indenture models for other systems now under development. Of significant note, as well, is the nationwide training program in RBS methodologies that the Navy has implemented since 1993.[Ref. 30] The Navy has also explored the concept of creating a single, national inventory based on RBS methods.[Ref. 31]

#### *c. Army*

The Army has used an improved version of METRIC called the Selective Essential Item Stockage for Availability Method (SESAME) for more than a decade in its initial spares budgeting and procurement decisions at the wholesale level.[Ref. 24: Chapter 9] Although initially used for communications and missile equipment, the favorable results prompted the Commander, Army Materiel Command (AMC) to direct that this model be used in all initial wholesale provisioning computations. In his directive of 16 April 1990, General Tuttle stated:

> [RBS] offers us the opportunity to improve our support to Army readiness at least cost...[RBS] is the way we want to do business in the future...[and] the benefits to be gained are such that we can not delay until all the existing policy and regulations are updated to reflect the change.[Ref. 32]

AMC has also used SESAME to support some initial issues of retail parts packages for newly fielded equipment. However, after the two year demand development period during which the item stock levels are protected under Stockage List Code "P", the items revert back to AR 710-2 rules. The items may then be eliminated from retail stock or have their stock levels reviewed and adjusted "noneconomically."[Ref. 14]

More recently, RBS methodologies have been used to determine prepositioned war reserves, sustainment war reserves and deployment packages. These models are being run using the Optimal Stock Requirements Analysis Program (OSRAP) developed by the Army Material Systems Analysis Activity. OSRAP also has the capacity to incorporate combat damage data from the Sustainability Predictions for Army Spare Components Requirements for Combat methodology which is based on detailed simulations of combat damage reports. AMSAA has more recently developed a PC-based version of this successful program for material managers at all levels called PC-OSRAP that operates in all current Windows environments.[Ref. 14; Ref. 33; Ref. 34] However, it is not currently integrated into the retail supply system and, where used, is predominantly for stand-alone, analytical purposes. A notable exception is OSRAP's recent adoption by the Louisiana Army National Guard which has, under severe operating budget restrictions, turned to RBS methodology for all of its stockage requirements.[Ref. 35]

### 3. Lessons Learned

The various commercial and military implementations of RBS methodologies have yielded several lessons learned. Sherbrooke, developer of METRIC, reminds his readers that:

> The stock levels from a model should not be treated like the Ten Commandments. No model embodies all of the day-to-day knowledge of experienced personnel. Thus, there will be occasions when model output should be adjusted.[Ref. 24]

However, he further adds that if it is necessary to *substantially* revise the output *on a regular basis*, as is now done with current AR 710-2 output, "the model needs to be improved." He also observes that:

> Although it may be possible to include every item on [a system] in a massive multi-echelon, multi-indenture computation, the problems of maintaining the database and all of the commonality information are formidable...that it makes sense to run the multi-echelon, multi-indenture model to an availability target for the group of important items and that a single indenture model run be made to a fill-rate target for the group of less important items that would require extensive data input to represent the commonality relationships otherwise.[Ref. 24: Chapter 9]

The Navy study of the RBS AVCAL corroborated that data management plays a key role. In their "real world" lessons learned, data quality was a major concern. Hale, in her analysis of that study observed that data quality

> ...is dependent on [sic] the accuracy of the historical data...[that] failing to document failures and repair times properly can lead to stocking too few or too many parts. An error in one direction is costly. An error in the other direction can degrade readiness.[Ref. 29]

Another data related lesson they learned was that essential maintenance data elements, such as failure rates, repair capability and repair turnaround times, were not available when the RBS AVCAL was developed. This deficiency resulted from the previous process not requiring such a maintenance data collection effort; therefore, it had not been built into their automated management systems.

The importance of indenture considerations was also revealed during the *America* deployment:

> Component indenture structure was not considered during *America*'s RBS AVCAL process, and this resulted in mismatches between parent repairable components...and the subcomponents needed to repair them...This subcomponent allowance deficiency resulted in longer than expected repair turnaround times which contributed to an increased number of cannibalization actions and hurt readiness.[Ref. 29]

The overarching lesson learned from the *America* deployment, however, was the acknowledgement that:

> Readiness is achieved from all integrated logistics support (ILS) resources – supply, maintenance, manning, and rear-echelon support...There are many ways to balance the ILS equation to achieve the desired level of readiness.[Ref. 29]

Recognizing that supply requirements have usually been determined *after* the other resources have been defined, Hale intimates the potential of a new role for the military logistician in which RBS is a tool that can be used to help treat readiness as a

production process in which the variety of inputs can be dynamically and optimally mixed to achieve the desired output.

# V. A COMPARATIVE PERFORMANCE ANALYSIS OF TRADITIONAL AND RBS POLICIES IN ARMY RETAIL INVENTORY MANAGEMENT

In the past several years, the Army Material Systems Analysis Activity (AMSAA) has conducted two major studies of RBS in Army retail applications. The first study, conducted during 1992-1993, consisted of field demonstrations at the National Training Center (NTC) and the 5th Infantry Division (Mechanized) (5ID(M)). Quantitative studies, including the 3rd Infantry Division (3ID) study discussed in Chapter III, were more recently conducted in 1996. In this chapter, we summarize the results of those studies and present appropriate analyses in light of previous discussions.

## A. FIELD DEMONSTRATIONS (1992-1993)

The first study sought to demonstrate the value of RBS methodology in Army retail inventory applications. The project was entitled Sparing to Availability in the Retail System Field Demonstrations (Sparing to Availability, or STA, the term used in the study, is synonymous with RBS; RBS is the term used hereafter for clarity). The specific objective of these demonstrations was to

> ...determine if the use of the [RBS] methodology provided cost savings while maintaining readiness and improving supply performance for field units when compared with ASLs computed using AR 710-2 and management discretion.[Ref. 36]

The 5ID(M) demonstration, conducted in December 1992, used an ASL only partially modified by RBS. The NTC demonstration, conducted in March 1993, used a

pure RBS ASL. The following sections summarize the findings from these demostrations.

### 1. Costs

ASL investment costs at both sites were less than that of the previously carried ASLs. Specifically, the RO value of the NTC ASL was reduced from $126.7 million to $68.7 million (net of the $14 million effect of implementing Stock Funding of Depot Level Repairables (SFDLR) that occurred during the demonstration period). Net asset levels (on hand, plus due in, minus due out) also decreased at both sites. Specifically, net assets at the NTC were reduced by $37 million (net of SFDLR effects). In addition, reductions in operating costs were anticipated at both sites based on storage, obsolescence and inventory losses.[Ref. 36: pp. v-vi,x]

### 2. Equipment Readiness

Equipment readiness, as measured by Equipment Mission Capable (EMC) and Non-Mission Capable Supply (NMCS) rates, improved with RBS. At NTC, the overall EMC rate increased from 66 to 82 percent. The NMCS rate (the amount of downtime attributable to supply delay) decreased from 9 to 6 percent. Even though a pure RBS ASL was not used at 5ID(M), that site still experienced a 20 percent reduction in NMCS rate.[Ref. 36: pp. vi,x]

### 3. Supply Performance

The study used a simulation called the Supply Performance Evaluator (SPE) to directly compare the performance of the pre-RBS ASLs with the demonstration ASLs.

Demands tracked during the demonstration period on the Monthly Transaction Registers were used as input in the simulation.

The RBS ASLs outperformed pre-RBS ASLs in all supply performance indicators. To demonstrate, the results for essential requisitions at NTC are shown in Table 4.

| MEASURE | PRE-RBS ASL | RBS ASL |
|---|---|---|
| Demand Accommodation | 64% | 81% |
| Demand Satisfaction | 70% | 88% |
| Fill Rate | 45% | 71% |
| High Priority Fill Rate | 48% | 72% |
| Ave. Zero Balance w/ Dues Out | 17% | 9% |

Table 4. Supply Performance results from the NTC demonstration, after [Ref. 36: pp. vii,x,40]

### 4. Mobility

A detailed mobility study was conducted as part of the 5ID(M) demonstration. The study concluded that the 5ID(M) could carry the RBS ASL with then organic equipment. Also, a portion of the mobility study specifically compared the physical characteristics of a pure RBS ASL with that of ASL on the ground as of January 1992. Those results are shown in Table 5. With RBS, even though the number of lines increased, both weight and cube of the ASL decreased.

| MEASURE | PRE-RBS ASL | RBS ASL |
|---|---|---|
| # of Unique Line Items | 8,483 | 10,335 |
| Weight (lbs) | 3.67 million | 1.63 million |
| Cube (cu ft) | 122,651 | 75,120 |

Table 5. Comparison of Physical Characteristics from the 5ID(M) Mobility Study, after Ref. 37

### 5. Manpower

Coincident with the mobility study, a manpower study was also conducted at the 5ID(M). This study concluded that minimal manpower impact was indicated overall as a result of implementing an RBS ASL. Observations also indicated that

> ...the number of items issued and received had a greater impact on manpower than the number of lines managed.[Ref. 38]

### 6. Transition to War

As part of the study, an analysis was made as to how well an RBS ASL would facilitate the transition to wartime operations. Using 5ID(M) data, this analysis compared pure AR 710-2 and pre-RBS ASLs with a pure RBS ASL used *as is* under simulated wartime conditions (accounting for increased OPTEMPO and estimates of combat damage). The results of the simulation are shown in Table 6. The RBS ASL outperformed both pure AR 710-2 and actual ASLs in all measures.

| MEASURE | PURE AR 710-2 ASL | PRE-RBS ASL | RBS ASL |
|---|---|---|---|
| Demand Accommodation | 70% | 76% | 84% |
| Demand Satisfaction | 84% | 88% | 89% |
| Fill Rate | 58% | 67% | 75% |
| High Priority Fill Rate | 60% | 69% | 78% |
| Ave. Zero Balance w/ Dues Out | 8% | 5% | 3% |

Table 6. Simulated Wartime Supply Performance of 5ID(M) ASLs, after Ref. 36, p. 63

## B. QUANTITATIVE STUDIES (1996)

Three quantitative studies were done by AMSAA in 1996. The first study used Armywide data from the Logistics Intelligence File (LIF) to characterize, among other things, the cost distribution of demand. The second study used demands accumulated in the 3rd Infantry Division from January to December 1996. This study not only included a characterization of the cost distribution of demand but also included a parallel study comparing the supply performance of an RBS ASL with the ASL as recommended by SARSS-O and the ASL carried by the division. The final study used demands accumulated in the 25th Infantry Division in a similar parallel study comparing the supply performance of an RBS ASL with their actual ASL.

### 1. LIF Study

This study was based on LIF data accumulated from June 1995 to February 1996. The data consisted of 591,958 high priority (Priority Designator,PD, 01-03) and included some common item requisitions. The study found that 70.1% of high priority requisitions

were for items with a unit cost of less than $50. Parts with a unit cost of $1000, or more, attributed to only 5.8% of the demand.[Ref. 19]

### 2. 3rd ID Study

This study was based on demands accumulated in the 3rd ID from January to December 1996. The parts cost distribution was similar to the study above. These results showed that approximately 69% of total demands (over 14 thousand) were for items with a unit cost of less than $50. Parts with a unit cost of $1000, or greater, comprised approximately 25% of total demand.[Ref. 19]

This study also compared the performance of RBS, SARSS-O (AR 710-2) and actual ASLs using the demand from the same period. The table below is similar to Table 2 in Chapter III, but it includes the RBS ASL and the results were generated for all *essential* requisitions. The RBS ASL was slightly more costly than the SARSS-O ASL but it was much less costly than that which was actually being carried. The RBS ASL again outperformed the other two in the three measured outputs.

| MEASURE | SARSS-O ASL | ACTUAL ASL | RBS ASL |
|---|---|---|---|
| Size | 5,604 Lines | 5,424 Lines | 11,612 Lines |
| Value | $28.6 Million | $80.3 Million | $34.3 Million |
| Demand Accommodation | 79% | 68% | 86% |
| Demand Satisfaction | 75% | 80% | 94% |
| Fill Rate | 59% | 54% | 80% |

Table 7. 3rd ID Performance Summary, after Ref. 19

### 3. 25th ID Study

This study is similar to the previous ASL comparison. In this case, however, the essential demands were accumulated from April 1996 to September 1996 and the RBS ASL is compared only with the actual ASL carried by the division. The results are shown in Table 8. As in the 3rd ID study, these results show that the RBS ASL provides superior performance, at less cost, over the actual ASL.

| MEASURE | ACTUAL ASL | RBS ASL |
|---|---|---|
| Size | 3,019 Lines | 5,164 Lines |
| Value | $8.4 Million | $5.7 Million |
| Demand Accommodation | 64% | 80% |
| Demand Satisfaction | 72% | 85% |
| Fill Rate | 46% | 68% |

Table 8. 25TH ID Performance Summary, after Ref. 19

## C. ANALYSIS

The combined results of these studies indicate that, in retail applications tested, the performance of RBS ASLs is consistently superior to those created under strict AR 710-2 guidelines and of those actually in use. The superior performance was consistent over ranges of time (1993-1996), type of unit (heavy, light), climate (desert, temperate, tropical) and OPTEMPO (peacetime, simulated wartime).

### 1. Nature of Demand

The results of the LIF study and the 3rd ID demand analysis suggest that a retail RBS ASL should provide a good *fit* to the readiness needs of customer units. Both indicate that the large majority of high priority demands (most of which, by definition,

are NMCS) are for low dollar items and relatively few demands are for high dollar items. RBS methodologies tend to stock more of low dollar items than high dollar items.

This observation is corroborated by the improved demand accommodation achieved by RBS ASLs over both pure AR 710-2 and actual ASLs. Accommodation improved from nearly nine percent (wartime scenario) to twenty percent (3rd ID) over pure AR 710-2 ASLs. The improvement was greater, overall, when compared to actual ASLs in use. Accommodation improved in each of these studies and in three out of four (NTC, 3rd ID, 25th ID), the improvement was at least 25%.

### 2. Cost versus Performance

#### *a. RBS ASLs versus Pure AR 710-2 ASLs*

The 3rd ID results did show that a RBS ASL can cost slightly more than a pure AR 710-2 ASL (as recommended by SARSS-O). The performance of the RBS ASL, however, was far superior to the AR 710-2 ASL. The three performance measures improved an average 23%. The greatest improvement was in gross effectiveness where the 20% additional investment over pure AR 710-2 resulted a 35.6% increase in fill rate. It is important here to recall that cost need not be an output from a RBS model; cost can be an input into the model thereby maximizing readiness for a given budget constraint.

#### *b. RBS ASLs versus Actual ASLs*

The results showed that RBS ASLs cost less than actual *on-the-ground* ASLs carried by either the NTC, 3rd ID or 25th ID. Although originated under AR 710-2, each of these ASLs had been modified during the ASL Review process. In the case of the 3rd

ID, this modified ASL cost nearly three times more. In this study, the RBS ASL improved the three supply performance measures by an average of thirty percent *at half the cost.* This result was consistent with that achieved six years earlier at NTC where each of the five performance measures improved by nearly 50% and readiness rates (EMC) improved by 24%, for 45% *less* investment.

### 3. Materials Handling

Both the mobility and manpower studies relate to issues in materials handling. Heavy and/or bulky items require more assets to lift, move and store them as compared to those less so. Likewise, more manpower is needed to operate the forklifts and drive the trucks.

The mobility study indicates that an RBS ASL can be lighter and less bulky than actual ASLs carried under current policy. Even though the RBS ASL carried over 20% more lines, it weighed less than half that of the pre-RBS ASL. Similarly, the RBS ASL required less than two-thirds the space. Although somewhat imprecise (due to line depth), a comparison of average weight per line and average cube per line can still provide useful insight. With RBS, the weight per line was reduced by 63.5% (433 lbs. to 158 lbs.) and the cube per line was reduced by 49.7% (14.5 $ft^3$ to 7.3 $ft^3$).

Also, many Army Combat Service Support units now use modern Commercial-of-the-Shelf (COTS) storage and retrieval systems, such as those provided by Stanly-Vidmar, Inc., in their warehouses *and* tactical vans.[Ref. 39] In the author's experience, these systems greatly improve storage efficiency for the smaller, lighter items seemingly

characteristic of RBS ASLs. The reduced size and weight in addition to increasing storage efficiency suggests that RBS is likely to increase mobility and reduce footprint while sustaining or improving readiness.

## D. IMPLICATIONS

### 1. There are barriers to implementing RBS in Army retail applications.

The concept of using RBS methodologies in Army retail applications is not new. Recall from Chapter IV that DoD specifically recommended RBS for retail applications as early as 1984. These techniques were also introduced to the Army by AMSAA at least as early as the 1980s.[Ref. 40] The field demostrations in 1993 confirmed that RBS can be effective in retail applications. Analysts recommended, *at that time*, that RBS

> ...replace the current AR 710-2 methodology for Class IX retail supply replenishment. [Ref. 36: p. 11]

Little further effort was made to pursue retail applications until the 1996 studies. As shown, those studies validated the 1993 findings. However, the value of RBS to retail policy was only tacitly recognized by its inclusion as an optional method for stockage determination in the current update of AR 710-2. As of this writing, RBS methodologies are not being considered in the near or mid-term by the Stockage Determination Process Improvement Team. The lack of acceptance of RBS in retail applications suggests there exist barriers to implementation of this policy option Armywide. We see two primary barriers to implementation of RBS, 1) cultural resistance to change and 2) information technology management.

#### *a. Cultural Resistance to Change*

Although there is only anecdotal evidence, to date, there appears to be apprehension by commanders exposed to RBS, despite findings that support using RBS. When the author inquired about the cause of apprehension, an AMSAA representative responded that commanders tended to think they were "losing control of their stock lists, even though we are not [advocating] fully going to centralized management."[Ref. 40] Another indicator is that further 1996 tests of RBS were cancelled due to "field mistrust of [the] items selected."[Ref. 33] Even the Deputy Chief of Staff for Logistics recently expressed concern over the "lack of high-dollar items in [an] RBS ASL."[Ref. 33]

It is possible that this apprehension stems from a lack of awareness and understanding of what RBS is and how it works. In conversations with numerous colleagues active in Army logistics related fields, the author has observed that, at least among that peer group, there is only a superficial understanding of RBS *at best*, if they have heard of the term at all. This lack of awareness and misunderstanding of RBS may lead to invalid assumptions and inappropriate conclusions concerning its implementation.

#### *b. Information Technology Management (ITM)*

ITM is a challenge in implementing RBS methodologies, particularly if one is to incorporate the full range of capabilities RBS offers. As was seen in the Navy's lessons learned, data collection and data integrity are issues that must be addressed. Improvements to current applications, such as PC-OSRAP, may have to be made to achieve appropriate utility on a day-to-day management basis. Finally, how to effectively

integrate RBS into current Logistics Information Systems architecture and those under development, such as the Integrated Combat Service Support System (ICS3), must also be addressed.

### 2. There is potential to overcome these barriers to implementation

The barriers to implementation are not insurmountable, however. We argue that perhaps the Army is entering into an unprecedented *window of opportunity* to implement RBS with a higher probability of success. Four factors contribute to this assessment.

#### *a. Field commanders are ready for change*

In a recent memorandum to the Chief of Staff, Army, dated 4 August 1997, the Commander, 1st Infantry Division (leader of U.S. forces in Bosnia) expressed his vision for the Army's future supply system.

> We should change the focus of our Divisional supply system from a peacetime, demand-based system, to one targeted at readiness for sustained combat operations...Additionally, we should tailor Division supply operations as part of the overall Theater/Wholesale system. What we stock on our shelves relates directly to the overall performance and philosophy of the greater system. We believe there are large efficiencies to be gained by attacking the supply system as a whole, vice addressing each of its pieces separately.[Ref. 39]

#### *b. Advances in information technology*

Advances in information technology have led the Army to integrate numerous data collection efforts and databases. These advances have recently enabled on-line, PC-based, user access to the Total Asset Visibility (TAV) and Work Order

Logistics File (WOLF) databases. The Logistics Integration Agency (LIA) is developing a Logistics Pipeline Analyzer that will provide

> …tactical, operational, staff and senior level managers the capability to review and analyze the performance for all segments of the Army's total logistics pipeline …[using] real time information … to perform trend, forecasting, and "what if" analysis on [a] specific segment or individual nodes.[Ref. 41]

With these and future advances, there may be the potential to systematically, and autonomically, share the necessary information with retail LIS to facilitate effective and efficient use of RBS at that level.

#### *c. Army XXI*

The Army's Force XXI development program provides a vehicle to insert, through experimentation, new technologies into ongoing organizational, doctrinal and systems reengineering processes. The redesign of Combat Service Support (CSS) for Division XXI having just been completed, combat developers are beginning the work on the CSS piece for Corps XXI. In that process, there exists the opportunity to rigorously consider RBS as an element of the total logistics system.

#### *d. Strategic Planning*

If implemented by the Army, RBS would represent a fundamental change in the way logistics is done at the retail level. As such, it is an issue of strategic importance to the organization as a whole. Implementation has the potential to, and should, affect not only inventory levels themselves, but also maintenance processes,

distribution processes, data collection processes, information systems, manpower, training, doctrine, culture and other organizational elements. The strategic planning process, in a holistic perspective, can facilitate change with systematic consideration of organizational design factors.

## VI. CONCLUSIONS AND RECOMMENDATIONS

*There will not be a revolution in military affairs unless there is a revolution in logistics*. – General Dennis Reimer, Army Chief of Staff, April 16, 1997

### A. CONCLUSIONS

Increasing readiness demands on the smaller force will continue to put pressure on Army commanders in the foreseeable future. In the near term, cuts in logistics infrastructure are likely to fund needed modernization efforts. In this context we have shown that:

#### 1. Current retail policy is no longer adequate to meet the readiness needs of the Army.

##### *a. Not explicitly linked to readiness*

The Army's current demand-based retail inventory policy is ill-suited to meet the readiness driven demands of the new Focused Logistics paradigm characteristic of logistics operations in the 21st Century.

##### *b. Not an effective decision support tool*

Current policy does not provide commanders and inventory managers adequate information to support the demands of decisionmaking in a dynamic environment where readiness needs must be continually balanced with fiscal reality.

### c. *Unintended effects with negative consequences*

Current policy generates numerous unintended, adverse effects that have serious consequences with respect to management of retail inventories, inventory cost and the ability of inventories to support readiness goals.

## 2. Readiness Based Sparing methodology is superior to current policy in Army retail applications.

Results of this study, and others, indicate that RBS is superior to current Army methods of stockage determination in retail applications. RBS is well established at the wholesale level of inventory management in all of the services. To date, RBS applications at the retail level have been limited in scope but have validated its effectiveness at that level. Navy experience with the Arleigh Burke destroyer class has demonstrated that implementation of RBS is achievable and can yield intended results.

## 3. Implementing RBS in Army retail applications is an issue of strategic change.

The implementation issue at hand is a matter of strategic change, not one of specifically technical barriers. The change must account for potential barriers to implementation. The change must also be considered within the context of the total logistics system. Policies on stockage determination and replenishment cannot be made in absence of consideration of their effects on the system. Specifically, inventory levels in the Army's multi-echelon, multi-indentured retail supply system are inextricably linked to repair cycle time and order ship time processes. With a readiness based sparing methodology, these variables be systematically related to quantify their impact on readiness outputs.

### 4. Conditions now exist that can facilitate strategic change in inventory policy.

RBS is consistent with, and supports, several of the mandates, vision statements and reengineering efforts at issue in the Army logistics community today. Some of these contemporary issues include Congressional mandates such as the output based measures of the Government Performance and Results Act of 1993, Army Vision 2010, Focused Logistics, Velocity Management, peacetime requirements, wartime requirements, and a commander's need for adequate decision support tools as steward for maintaining readiness in a fiscally constrained environment.

## B. RECOMMENDATIONS

### 1. Embrace Readiness Based Sparing as the preferred method of stockage determination for Army retail applications.

We recommend that the Army actively pursue Readiness Based Sparing as the preferred method for retail inventory management. In support of this effort, we specifically suggest 1) identifying via survey, or other appropriate means, the specific apprehensions many decisionmakers and field commanders apparantly have about RBS, and 2) increasing awareness and education of RBS methodologies among Army logistics professionals focusing not only on the potential benefits of RBS, but also on how and why it works.

### 2. Use the Army XXI redesign process as the mechanism for strategic change to implement RBS at the retail level.

We recommend that combat developers at the Combined Arms Support Command use Readiness Based Sparing as a core technology about which to redesign the

logistics force for Army XXI. We further recommend that a Proof-of-Principle (POP) test be conducted at Fort Hood with the Army's Experimental Force (EXFOR). This POP should be vertically integrated for an entire weapon system, such as the M1A1 Tank. Conducting a POP at this location offers the unique opportunity to evaluate RBS within the Division XXI CSS force structure while including Direct Support, General Support, and Installation activities and using the repair pipeline data resources available from the Regional Integrated Sustainment Maintenance (RISM) office located there.

**3. Continue research and experimentation in RBS methodologies to evaluate the full potential of the technology in Armywide applications.**

We recommend that the Army evaluate the full range of capabilities that RBS methodologies may offer. The potential benefits of RBS may only best be realized with due consideration of the multi-echelon, multi-indenture problem at retail and wholesale simultaneously. RBS is an enabling technology that can leverage improvements in Order Ship Time and Repair Cycle Time reduction. Toward this end, we specifically suggest 1) quantifying the impact of varying RBS objectives and constraints (and subsequent inventory levels) on Repair Cycle and Order Ship Times, 2) quantifying the degree to which a RBS policy contributes to, or mitigates, the bullwhip effect, and 3) identify the potential value to the Army of RBS in a single inventory system that integrates wholesale and retail levels.

## APPENDIX: INTRODUCTORY METRIC THEORY

### 1. Background

This summary is based on the work of Craig Scherbrook and excerpts from lectures presented by the primary advisor for this thesis [Ref. 24; Ref. 25; Ref. 26; Ref. 28]. It will focus on treatment of repairable components of end items. Compared to consummable items, repairables typically cost more, are demanded less frequently and have longer lead times. Another characteristic of repairables is that they are *memoryless* meaning that the time to the next failure is not dependent on the time since the last failure. The memoryless distribution is the exponential distribution. When the time between failures follows the exponential distribution, then the number of failures expected over any fixed time period is given by the Poisson distribution. Accordingly, the Poisson distribution is used. Empirical evidence shows that the Poisson distribution provides a reasonable stochastic model to describe the occurrence of failures of most repairable items.

Another characteristic of the Poisson process is its adherence to Palm's Theorem. It states that:

> If demand for an item is a Poisson process with annual mean $m$ and if the repair time for each failed unit is independently and identically distributed according to any distribution with mean T years, then the steady-state probability distribution for the number of units in repair has a Poisson distribution with mean $m$T.

In less rigorous terms, suppose average annual demand *m* for M1 Tank engines at Fort Hood is 120 and that mean repair turnaround time (RTAT) is 36.5 days yielding T equal to 0.1. The demand is Poisson, for reasons stated above, and the RTAT of one engine does not depend on the RTAT of any other but does follow some, perhaps unknown, distribution. Palm's Theorem states that, regardless of the distribution of repair times, the expected number of engines in the repair *pipeline* at any time follows a Poisson distribution with mean *m*T. In this case, a random observer would expect to see a backlog of 12 engines.

Finally, recall the observation that for corrective maintenance actions on critical items, the readiness cost of a stockout is the time it takes for the backorder to be filled. Consequently a rigorous treatment, beyond the scope of this study, can show that minimizing the expected number of backorders corresponds to maximizing operational availability, $A_o$, where $A_o$ = MTBM /(MTBM+MDT) and MDT = MTTR + ACWT.

### 2. The Single Site Model

In the single site algorithm, as with those that follow, we will achieve the goal of maximizing availability by seeking to minimize the expected number of backorders (EBO) systemwide. To accomplish this goal, we turn to marginal analysis. Given a specified budget and a number of candidate stock items , the algorithm is as follows:

- For each item (at stock level $s = 0$) with cost $c$, compute the quantity, $\Delta$ as

$$\frac{\text{EBO}(s) - \text{EBO}(s+1).}{c}$$

  This value, $\Delta$, is the marginal decrease in expected backorders (marginal increase in $A_o$) per unit cost obtained by adding one additional unit of stock. Actual EBO values are readily calculated from cumulative probabilities of the Poisson distribution.

- Add to the inventory one unit of that item having the highest value of this expression and subtract its cost, $c$, from the available budget.

- Continue adding units of items to the inventory until the available budget is consumed.

Consider a two item example in Tables 9 and 10. For each item, at various stock levels, $s$, the EBO($s$) and $\Delta$ values are calculated as shown in the table. Notice that before we stock any items ($s = 0$ for each), the expected backorders for each item are exactly equal to the pipeline, 1.000 and 4.000 respectively, for a total expected system backorders of 5.000. The first $\Delta$'s (at $s = 1$)for the two items are .126 and .982 respectively, so we choose to add one of Item 2 which yields the greatest reduction in the number of expected backorders. Subracting the unit cost of Item 2 ($1000) from the available budget (say $18,000), we then compare $\Delta_{(s=1)}$ for Item 1 with $\Delta_{(s=2)}$ for Item 2. Obtaining 0.126 and 0.908 respectively, we again choose to add another of Item 2. We continue in like fashion until we compare 0.126 with 0.111 at which time we add the first unit of Item 1. Continuing until the available budget is consumed yields final stock levels of 2 each of Item 1 and 8 each of Item 2 with a total expected system backorders of 0.138.

| ITEMS | 1 | 2 |
|---|---|---|
| Mean annual demand *m* | 10 | 50 |
| Average repair time *T* | 0.1 | 0.8 |
| Average pipline ($\mu$=*mT*) | 1 | 4 |
| Item cost ($000) | 5 | 1 |

Table 9. Two item example, from Ref. 24

| | ITEM 1 | | ITEM 2 | |
|---|---|---|---|---|
| s | EBO(*s*) | Δ | EBO(*s*) | Δ |
| 0 | 1.000 | | 4.000 | |
| 1 | 0.368 | 0.126 | 3.018 | 0.982 |
| 2 | 0.104 | 0.053 | 2.110 | 0.908 |
| 3 | 0.023 | 0.016 | 1.348 | 0.762 |
| 4 | 0.004 | 0.004 | 0.782 | 0.567 |
| 5 | 0.001 | | 0.410 | 0.371 |
| 6 | 0.000 | | 0.195 | 0.215 |
| 7 | 0.000 | | 0.085 | 0.111 |
| 8 | 0.000 | | 0.034 | 0.051 |
| 9 | 0.000 | | 0.012 | 0.021 |

Table 10. Expected Backorder (EBO)Table, from Ref. 24

### 3. The Multi-echelon Problem

The single site model indroduces the mechanics of how a readiness based model works, however, there are several reasons why the need for a multi-echelon inventory model is significant. The first reason is that a multi-echelon model more accurately imitates the complexity of military supply and maintenance systems. Second, as seen in Chapter III, intuition can be unreliable in even relatively simple resource allocation

problems. Also, consider demand that might not justify stockage at any given retail point; that same demand, when aggregated, might justify stockage at some central point. Finally, making good decisions at one location while ignoring like decisions at others and those of supporting activities still suboptimizes the the total system. A multi-echelon model optimizes the total system by accounting for the attributes of each activity at each echelon.

The Multi-Echelon Technique for Recoverable Item Control (METRIC) is an example of such a multi-echelon inventory model. First developed for the Air Force in 1968, it extends the previous single-site model to handle situations where multiple bases are supported by higher level activities called depots (the terms base and depot are applied generically to facilitate discussion). Although it can apply to any number of echelons, we will address only the two-echelon problem here.

In a two-echelon, closed system (a closed system, assumes all assets are repairable, washouts and depot resupply are addressed later), there are one depot and several bases. For a given item that fails at a base, there is a probability that the item will be repaired at the base and otherwise it will be repaired at the depot. There are two stages in executing the METRIC model. The first step is to find the optimal cost-backorder curve for a single item. The second step is to then combine all items in a system using marginal analysis to establish an optimal system availability cost curve.

The first step in obtaining the optimal cost-backorder curve is to determine the expected pipeline at the depot. This pipeline is exactly analogous to the pipeline

described in the previous discussion of Palm's Theorem. The pipeline at the depot consists of the demand for the item seen at the depot and the RTAT for that item at the depot. The demand at the depot is calculated from the total demand at each base, times the fraction not repaired at the base, summed over all bases. This *net* demand is then multiplied by the RTAT at the depot to obtain the pipeline value.

From this value and the OST from the depot to the bases, the expected resupply delay time to the bases is determined. Note that this expected resupply delay time is a function of the ready for issue stock level of the item, if any, maintained at the depot. To illustrate, assume the depot held an infinite supply of the item in stock; the resupply delay will only be the OST. Conversely, if the depot held no stock, then the expected resupply delay is the OST plus the RTAT. The expected resupply delay at various levels of stock lies between those extreme values and is readily calculated stochastically. Next, the individual pipelines at each of the bases is calculated from the portion of the base pipeline in repair locally (the remaining fraction of demand repaired locally times the local RTAT) and the expected resupply delay at the depot.

Then, as in the single-site model, the expected backorders at bases can be calculated from the pipelines at each of the bases. A table is generated for each base that shows the EBO and decrease in EBO for each of the item stocked at the base. A set of these tables is generated for each level of depot stock because as depot stock increases, the pipeline at the bases decreases due to the resultant reduction in expected resupply delay. Then, a table is generated that shows the total system expected backorders for all

possible allocations, among the depot and bases, of a given system stock level. The final task is to optimally allocate stock to the depot and bases to minimize the total expected system backorders.

Finding the system availability-cost curve, step two of METRIC, is accomplished by completing step one for each item in the system and then using marginal analysis to determine the most cost effective mix of items, optimally allocated, to meet the system readiness goals.

The two-echelon, closed system algorithm just described, although somewhat rudimentary, is still obviously a quite complex, computationally intense, iterative process that can not be fully addressed in this discussion. A rigorous development, with accompanying tables, is found in the cited reference. As well, the theory is expanded to incorporate muliple echelons, depot resupply, washouts, multi-indentured parts, lateral resupply, cannibalization and other factors. Inclusion of these factors leads to correspondingly increasing complexity as they seek to better emulate real processes. However, numerous commercial and military software applications based on these models are currently available to address this problem.

In review, the METRIC model provides a method to optimally determine where to position inventory in a multi-echelon system such as the Army's supply and maintenance system. Acknowledging that stock level at a base depends on order ship time, depot and base repair rates, and other things, this model provides a way to compute inventory savings from improvements in these processes. This tool would facilitate ongoing and

continuous Army efforts in order ship time and repair cycle time reduction by their respective process improvement teams mentioned in earlier chapters.

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## LIST OF ACRONYMS

| | |
|---|---|
| AMC | Army Materiel Command |
| AMSAA | Army Materiel Systems Analysis Activity |
| ASL | Authorized Stockage List |
| ASLP | Army Strategic Logistics Plan |
| AVCAL | Aviation Coordinated Allowance List |
| BSL | Bench Stock List |
| CASCOM | Combined Arms Support Command |
| CAN | Center for Naval Analysis |
| CONUS | Continental United States |
| COTS | Commercial-of-the-Shelf |
| CSS | Combat Service Support |
| DCSLOG | Deputy Chief of Staff for Logistics |
| DOS | Days of Supply |
| DS | Direct Support |
| DSU | Direct Support Unit |
| EBO | Expected Backorders |
| EMC | Equipment Mission Capable |
| EOQ | Economic Order Quantity |
| EXFOR | Experimental Force |
| FORSCOM | Forces Command |
| GS | General Support |
| GSU | General Support Unit |
| ICS3 | Integrated Combat Service Support System |
| ITM | Information Technology Management |
| LIA | Logistics Integration Agency |
| LIF | Logistics Intelligence File |
| LIS | Logistics Information System |
| LSP | Logistics Strategic Plan |
| METRIC | Multi-echelon Techniques for Recoverable Item Control |
| MTOE | Modified Table of Organization and Equipment |
| NMCS | Non-Mission-Capable-Supply |
| NRFI | Not Ready for Issue |
| NTC | National Training Center |
| OL | Operating Level |
| OPTEMPO | Operations Tempo |
| OSRAP | Optimal Stockage Requirements Analysis Program |
| OST | Order Ship Time |
| PIT | Process Improvement Team |
| PLL | Prescribed Load List |
| POP | Proof of Principle |
| RBS | Readiness Based Sparing |
| RCL | Repair Cycle Level |
| RCT | Repair Cycle Time |

| | |
|---|---|
| RFI | Ready for Issue |
| RISM | Regional Integrated Sustainment Maintenance |
| RMA | Revolution in Military Affairs |
| RML | Revolution in Military Logistics |
| RO | Requisitioning Objective |
| ROP | Reorder Point |
| SARSS-O | Standard Army Retail Supply System - Objective |
| SESAME | Selected Essential Item Stockage for Availability Method |
| SFDLR | Stock Funding of Depot Level Repairables |
| SL | Safety Level |
| SLC | Stockage List Code |
| SPE | Supply Performance Evaluator |
| SSA | Supply Support Activity |
| SSL | Shop Stock List |
| TAV | Total Asset Visibility |
| VM | Velocity Management |
| WOLF | Work Order Logistics File |

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   Aberdeen Proving Ground, MD 21005

8. Director ....................................1
   US Army Material Systems Analysis Activity
   ATTN: AMXSY-LM (Dave Seibert)
   Aberdeen Proving Ground, MD 21005

9. CPT Robert D. Brem ..................................................5
   1703 Carver Square
   Salisbury, MD 21801-7040